## Editor

**Justification (visible to authors and reviewers only)**:
Dear authors,

Thank you for your submission to TC/TCD. As you may know, papers accepted for TCD appear immediately on the web for comment and review. As a consequence, before publication in TCD, all papers undergo a rapid access review undertaken by the editor and/or reviewer with the aim of providing initial quality control. It is not a full review and the key concerns are fit to the journal remit, basic quality issues and sufficient significance, originality and/or novelty to warrant publication. The criteria for this evaluation can be found at http://www.the-cryosphere.net/review/ms_evaluation_criteria.html. Grades are from 1-4 (excellent-poor).

Scientific Quality (Rigour): 2
The scientific rigour of the paper appears sound; the objectives are clearly outlined, the methodology is suitable, and the results are discussed appropriately. I would like to see a bit more discussion on the uncertainty of the results. For example, there is uncertainty in ERT results due to data noise, filtered data points, choice of inversion parameters (norms, regularization parameter, noise levels), and resolution limitations. These factors may also help to explain the difference between laboratory and field results but are not really discussed.

Significance (Impact): 2
The stability of permafrost rockwalls is certainly an important topic, as it affects the safety of people and infrastructure in populated alpine regions. This manuscript builds on previous works that have used ERT to characterize permafrost and shows how temporally dense automated ERT measurements can be used to monitor changing conditions over time in rockwalls. The manuscript would benefit from a statement in the conclusions section that highlights the broader significance of this work in terms of understanding and predicting geohazards.

Presentation Quality: 1.
The paper is well written, clear, and the figures are appropriate. In summary, the paper is an interesting contribution and would be a good fit for The Cryosphere's special issue on emerging geophysical methods for permafrost investigations.

Kind regards,

Teddi Herring (handling editor)

**Answer to Editor:** We would like to thank the editor for managing this manuscript and for the valuable comments that helped improving its quality.

We have taken into account in the new version of the manuscript the points raised by the editor and the reviewers.

## Responses to reviewers

## Reviewer 1:

We thank the reviewer for his valuable and insightful comments, which have helped improve this manuscript. Below, we provide our responses and explanations to the points raised and we have incorporated all minor comments into the revised text.

1- The manuscript titled "Rockwall permafrost dynamics evidenced by Automated Electrical Resistivity Tomography at Aiguille du Midi (3842 m asl, French Alps)" presents repeated ERT measurements in a high-alpine environment, complemented by laboratory experiments and a comparison of measured borehole temperatures with ERT-derived temperature estimates. The dataset is not entirely unique in terms of elevation, as it represents only a partially higher-altitude setting with conditions comparable to other study sites and publications. While we acknowledge the effort involved in obtaining and processing this dataset, we recommend major revisions.
Specifically, the manuscript would benefit from a clearer articulation of its novelty and research objectives. At present, the focus and unique contribution of the study remain somewhat unclear. The identified research gap – namely, that A-ERT at high altitudes has not yet been tested for long-term permafrost monitoring – is relatively weak. As a result, the study's aim appears vague, and the added value or benefit of the findings remains insufficiently presented and discussed. Furthermore, we encourage a more transparent presentation of the dataset, particularly regarding its temporal and spatial coverage (see specific comments below).

**Answer**: we want to highlight that the novelty of our work lies in the multi-year high-resolution A-ERT dataset obtained at the Aiguille du Midi site that provides new detailed insights into temporal permafrost dynamics. The Aiguille du Midi presents a unique setting due to its complex structure steep rock faces with varying aspects (massif and fractured rocks), human made infrastructure, and challenging accessibility. Furthermore, we highlight the challenges to get such dataset at that harsh climate conditions that could be very useful for future works. However, we tried to clarify our main objectives and advances in the new version:

- Testing potential of A-ERT to assess permafrost dynamics ➔ all previous studies are over < 1 year and therefore do not address permafrost dynamics, in Offer et al., 2025, several years but not comparable dataset over several years. Repeated measurements that are different from automated measurements do not assess the infra-seasonal changes, so our approach aims at assessing permafrost evolution over various time scales. Furthermore, our study also covers different rock faces with very different thermal and hydrological regime and it highlights the variability of these processes as well as the variability of some practical issues from one face to another
- Test potential of A-ERT to detect short term changes that could be due to water flows ➔ previous studies report such findings but in different lithologies, over different time scales. These methods are emerging and this study contributes to exploring its potential in different settings
- Test the possibility to calibrate the temperature-resistivity relationship *in-situ* to overcome some limitations inherent to laboratory experiments ➔ our study brings the very first *in-situ* calibration and provide some perspectives on the limitations of lab measurements. It also shows the difficulty of accurate/precise calibration in the

shallowest layers (~0-4 m) that are layers that are also the most difficult to accurately simulate with heat transfer models due to the complexity of heat transfer processes that involves air circulation, water infiltration, icing, latent heat exchanges and heat conduction (Magnin et al., 2017 ; Legay et al., 2021).

We will clearly articulate our research questions, emphasizing the value of long-term continuous A-ERT monitoring in a complex high-alpine environment. We will highlight the unique characteristics of the Aiguille du Midi and explain how our study addresses the specific challenges of monitoring permafrost dynamics in this setting.

Main concerns

2- Novelty **and previous studies:** The methods applied in the A-ERT monitoring (e.g., Keuschnig et al., 2017; Mollaret et al., 2019), the inversion routines, and the laboratory calibration approaches (Krautblatter et al., 2010; Magnin et al., 2015; Scandroglio et al., 2021; Etzelmüller et al., 2022, Offer et al., 2025) are well-established. Several parts of the lab analysis and interpretation closely resemble those of previous studies. We recommend reconsidering the novelty of your study – possibly by applying new or more advanced analyses – and restructuring the manuscript accordingly. The stated goals (1–3) at the end of the introduction have been substantially addressed in prior work (e.g., Keuschnig et al., 2017; Mollaret et al., 2019, Scandroglio et al., 2024, Offer et al., 2025). Clarify what differentiates your approach or findings from those.

**Answer**: Keuschnig et al., 2017 ➔ 1 year of measurements, therefore no infomration on the permafrost evolution that is a pluriannual evolution. Mollaret et al., 2019 ➔ repeated measures that are not A-ERT (see further comments below where it is stated that « which raises the question of whether A-ERT truly offers advantages over occasional repeated campaigns » One objective of this paper is to address this question to determine what we can gain from both pluriannual measurements and infra-seasonal measurements.

3- Abstract (Lines 44–47): The abstract should clearly state the main goal of the study. As currently written, it reiterates that ERT is effective in permafrost studies – something that is already well-known (Herring et al., 2023). The methodological innovations or scientific contributions are not emphasized enough. Please revise this to highlight what is new or different in your approach or findings.

**Answer**: the introduction was revised in the main text to clarify the main goals and findings of this work.

4- Time period and spatial coverage of A-ERT monitoring: The abstract states that monitoring occurred from 2020–2023. However, there are no measurements before June 2020, and between June 2020 and September 2021, ERT acquisitions were only conducted occasionally. Furthermore, significant data gaps occurred from summer 2022 onward on the NW-facing profile, and from summer 2023 on, due to cable failures. These sparse measurements (occasional repetition and cable defects) do not constitute continuous monitoring. Please clarify the actual continuous data availability in the entire manuscript (maximum of 2 years instead of 4 years).
Moreover, the east profile, although included in the inversion models, is not adequately analyzed, particularly in terms of contact resistance, average apparent resistivity, and its

temporal evolution. Why not analyze this profile more comprehensively? You mentioned problems with data gaps, however, data sets of the E profile are included in the inversions. Furthermore, the interpretation relies on a limited number of selected tomographies, which raises the question of whether A-ERT truly offers advantages over occasional repeated campaigns – given this, the conclusions appear overstated.

With reference to the selected data presented in Table 1, it remains unclear how representative these data are. We recommend clarifying the criteria for their selection and discussing to what extent this choice may influence the overall findings and interpretations.

**Answer**: the East face cable was damaged by a lightning strike days after installation. That is why no longer analyses were done on this side. The data presented go back to the installation day and at this day some electrodes were not connected because of high contact resistance as mentioned in the text and in the caption of the figure. The period of A-ERT is about 2.5 years. However, measuring in winter (e.g., from October to march) looks very difficult to realize. Even if we could measure in winter the data are unexploitable (most of electrodes are disconnected). Offer et al (2025), showed the same problem a gap in the dataset of A-ERT in winter because of high contact resistance.

Offer, M., Weber, S., Hartmeyer, I., Keuschnig, M., Rau, M., and Krautblatter, M.: From ice-filled fractures to pressurised water flow in permafrost bedrock: seasonal changes in rockwall hydrology, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-15585, https://doi.org/10.5194/egusphere-egu25-15585, 2025.

Other points are discussed in the new version of the manuscript.

5- Laboratory calibrations: We disagree with the statement that the temperature–resistivity dependency is less pronounced in field conditions. Rather, the temperature–resistivity relation remains consistent, but it is often influenced by discontinuities, not captured in lab samples.
The manuscript presents calibration data from only one sample (and one electrode array!) taken directly from the study site, while the second sample originates from the lower Cosmiques ridge and may not be fully representative. We strongly recommend additional tests using multiple samples and/or multiple array configurations on each sample to characterize variability and quantify uncertainty. Prior studies (Krautblatter et al., 2010; Magnin et al., 2015; Scandroglio et al., 2021; Offer et al., 2025) have demonstrated the considerable range in temperature–resistivity relationships between different rock samples and even within individual electrode arrays. Your main interest lies between the temperature range from -5 to +5°C, but you only show five observations for each sample with only one point on the freezing path. Please address this in your further laboratory testing.

Furthermore, in Line 540, it is stated that resistivity in frozen conditions is primarily dependent on temperature, while other parameters are assumed to be constant. We would like to clarify that resistivity in freezing rock is primarily controlled by the remaining unfrozen pore water content, which in turn strongly influenced the pore water salinity. Porosity, by contrast, remains constant in both frozen and unfrozen states and should not be considered a temperature-dependent variable in this context. Finally, we question the decision to perform the calibration tests using vacuum saturation with degassed water. Why was this approach chosen over using snowmelt water from the field site and applying atmospheric pressure conditions? The latter would be more realistic for field conditions.

**Answer**: we mentioned that the relationship is "less pronounced" regarding the field results in comparison to laboratory, which could be influenced by the heterogeneity and discontinuities of the medium and could be influenced by the data quality, leading to this observation as you explained and we explained that in the text. We will clarify the idea about resistivity in frozen conditions.

Theoretically, configuration of electrodes should not influence the measured resistivity, as it is an intrinsic property of the sample. We use a standard method to measure the resistivity with current injection at both sides of the cubic sample to ensure homogenous distribution of current density in the sample, and in this case, the calculation of the geometric factor is easier (which reduces uncertainty related to the calculation of the geometric factor). Testing different samples: the site consists of massive granite as found from the boreholes, the heterogeneity and discontinuities at higher scale (fractures) could not be captured by testing other samples. Lower Cosmiques ridge is basically the same site. Furthermore, one of the main advantage and novelty of our paper is that we perform in-situ calibration.

We used vacuum saturation with degassed water to insure 100% saturation of small pores (where capillarity effect is very high) and for faster saturation than in atmospheric pressure conditions. The conductivity of the saturated water is close to the conductivity of water collected in the gallery of the AdM.

6- Data Processing and Inversion Parameters: Please clarify the following points regarding your data processing:
   - How are outliers defined (Line 288)?
   - Why was a linear error model with 5% chosen? What is the absolute error?
   - Which inversion parameters were applied, especially lambda, paraDepth, quality, and z-weighting?
   - Include chi² values for all inversion results, as the model mesh appears very fine, with little growing with depth, raising concerns about overfitting of the data.

   - Fig. 13 (P1) shows that you already obtain eight resistivity values for a depth<2m, which seems to be inappropriate for an electrode spacing of 5m. We would highly recommend adapting the mesh.

     In addition, we advise against using measured apparent resistivity directly for trend analysis. The instrument may apply incorrect geometric factors, which could distort your results. Reanalyze the data using resistance or properly computed apparent resistivity (e.g., using pyGIMLi) for greater reliability.

**Answer**: the processing made here are more technical process. And we think that they are not important to integrate in the text. I will explain the processing here:

1- We agree with reviewer that the device will not provide the right apparent resistivity, that is why we have already used the measured resistance and then we used pyGimli library to calculate the apparent resistivity (after considering the real positions of electrodes).
2- for the analysis and outliers filtering: we analyzed individually few pseudosections (at different times (summer, spring, etc…), as a result of this analysis we decided to apply filter outliers out of range (300Ωm - 20 kΩm) for data measured in summer and autumn. And out of range (300Ωm - 200 kΩm) for data measured in spring and winter.

More data filtered at higher resistivities, where data quality are usually poor (see figure 5 in the new version).

3- For the inversion of a dataset: the first concern is the high Contact Resistance (CR) which could lead to disconnected electrodes once a CR threshold is exceeded. To address this issue, only pseudosections with a maximum of three disconnected electrodes were retained for inversion.

- As we don't have an accurate estimation of errors, we used a linear error of 5% as usually used in permafrost studies. (Mollaret et al., 2020). We tested different values of absolute error, and it has ne influence on the result, so we used a value of 1e5.
- We presented RMS (%) at each inversion figure and as you can find in the next figure both RMS (%) and $\chi^2$ are close and have the same trend.

For the inversion parameters: we made analyzes of the inversion parameters of a reference model. To reinforce the vertical discontinuities (related to the active layer or the infrastructure) in the AdM, we started by choosing the (zWeight > 1), and later with iterative processes we determined the smoothness parameter (Lambda). And we followedthe recommendation of (pyGIMLI creators) mesh quality =34.4, while paraDepth=10.

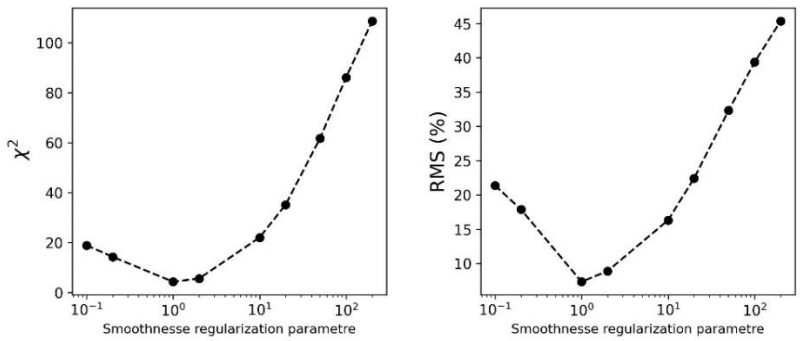


Figure 1: Iterative process to find the smoothness parameters and other parameters of the mesh.

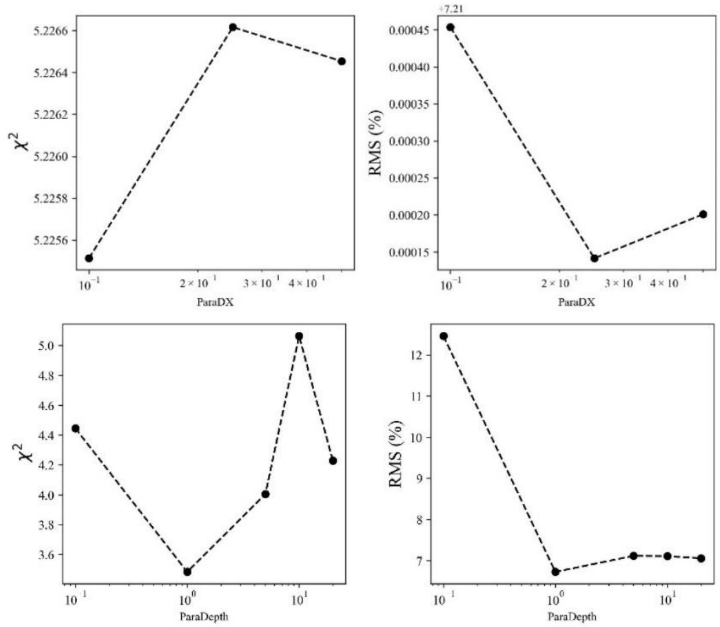


Figure 2: Iterative process to find the parameters of the mesh (paraDx and ParaDepth).

Inversion parameters (zWeight=10, lambda=1, paraDx=0.5, ParaDepth=10, quality=34.4)

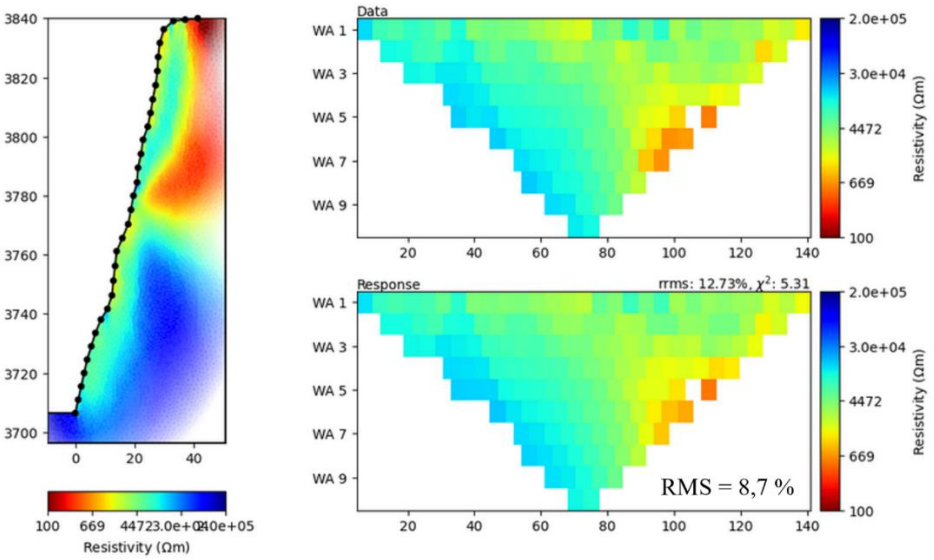


Figure 3: Example of the inversion of the reference dataset used to get the inversion parameters.

7- Figures – numbers, quality and color schemes: The manuscript includes a large number of figures, which makes it difficult to follow the overall narrative. We suggest reducing the number of figures in the main text – moving less essential ones to the appendix or supplementary material – and clearly emphasizing the main findings of each figure, either through improved visual presentation or more informative captions. Nearly all figures are not colorblind-friendly, particularly those using red and green together. Please revise all color schemes accordingly. Additionally, the choice of colors should support the

interpretation of the data more effectively. For instance, in Figure 4, consider using clearly distinguishable colors to differentiate between excluded and retained datapoints.

**Answer**: we reduced the number of figures by merging some and moving the less essential figures in the appendix. Concerning the color schemes it is commonly used, we tested many other color schemes, but the one used here represents better results.

In Figure 4 we want to show the general evolution of contact resistance of all electrodes and the gaps in the A-ERT.

8- **Figure 5**: The figure is difficult to interpret. The bars are barely readable, and the intended comparison is unclear. Are you examining interannual changes or comparing specific time periods? The same question arises for Figure 9-12 – what is the focus of the study? In the current layout, it is complicated to distinguish between interannual and pluriannual changes.

**Answer**: Figure 5 was simplified in the new version. We try to show a comparison of seasonal and interannual datasets (three datasets in each subfigure), to get an idea about the seasonal variation and interannual variations at each side of the site.

9- Figure 6: Rather than indicating the number of electrodes, specify the depth of investigation. It would be more appropriate to present inverted resistivity values here. The connecting lines between data points suggest a linear trend, which may misrepresent the actual physical behavior – particularly during the transition between unfrozen and frozen conditions. We therefore suggest removing these trend lines to avoid a misleading interpretation.

**Answer**: The objective is to show the variations in the raw data at different positions of the profile. We added in the legend the theoretical depth of investigation. For the trend line it could mislead the reader but it helps as eye guide (here example of the figure without lines): but we prefer to keep them and to add in the caption that (The dashed lines are just guides for the eyes).

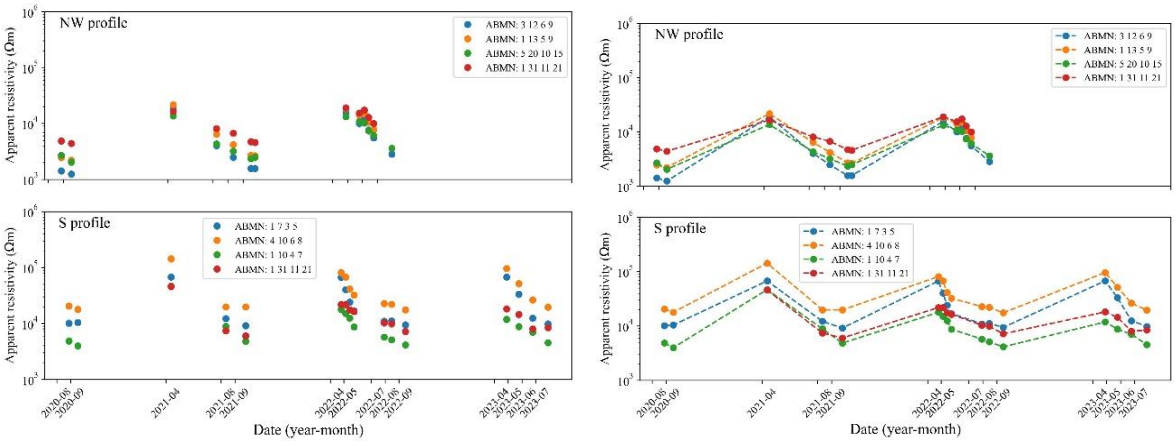


Figure 5: Temporal changes in apparent resistivity for different combinations of quadrupoles (ABMN) 341 reflecting different depths of investigation. (Figure was removed in the new version)

10- **Figure 7**: This figure compares resistivity across multiple profiles. However, a direct comparison is problematic due to differences in profile orientation—P1 is oriented perpendicular to the surface, whereas the others are nearly horizontal. In addition, it would be helpful to indicate the expected permafrost extent and the corresponding threshold resistivity values (subfigure). We also recommend adjusting the color scale: resistivity values as high as 500.000 Ωm are not physically explainable and should be limited. The grey lines representing the infrastructure are barely visible.

**Answer**: P2 and P4 are almost perpendicular to the surface. The extent of active layer varies from one profile to another. We add information in the appendix about the active layer extent from boreholes data. We will improve the quality of the figures.

11- **Figure 9-10**: It appears that different meshes were used for the inversion routines and the subsequent calculation of resistivity change ratios. This inconsistency should be addressed. We also recommend using consistent x- and y-axis limits in both figures.
**Answer**: the same mesh was used for the calculation of resistivity change ratio and the same mesh in both figures 9 and 10; only the x-axis ticks have been changed in display. We have corrected this point in the new figure.

12- **Figure 11**: The red arrows overlaid on the tomograms obscure important details. Additionally, mark the locations of observed drainage paths in Figure 12 for better correlation between figures.
**Answer**: we moved the arrows in figure 11 and added arrows on fig 12.

13- **Borehole validation:** In the discussion, it is stated that borehole temperature data were used to validate both the interpretation and the estimated temperatures (Lines 486–487). The borehole temperature data of the different boreholes are not included; however, the manuscript would greatly benefit from a visual representation of borehole temperatures over time, ideally aligned with the ERT measurement periods and on the north/ south-facing slope. This could include a figure showing active layer thickness evolution over the years.

You presented two calibration curves from the laboratory testing – please clarify which one (and why) was used to estimate temperature. In Figure 14, estimated temperatures below 2 meters are missing, although Figure 13 shows that 13 resistivity values were extracted from profile P1. Why are these data points excluded? Also, consider adjusting the x-axis of Figure 14; the current range (-10°C to +10°C) is unnecessarily broad.
In Line 553, you mention that individually adapted inversion parameters can improve temperature estimation – why does not show a comparison to demonstrate this?

Lastly, when comparing laboratory and field-derived resistivity–temperature relationships, please account for differences in the penetration depth of the current signal.

**Answer**: We mentioned in the text the essential information from boreholes (e.g., maximum depth of active layer at each borehole). And we refer to the study where all data are treated explicitly, and we added in the appendix the following figure to visually represent temperature in borehole over time of ERT at south/north faces as proposed.

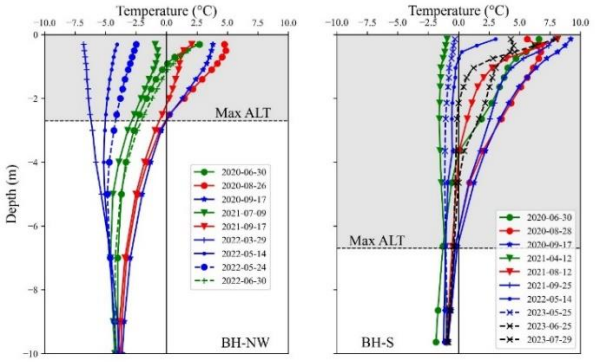


Figure 6: Temperature variation over depth in boreholes BH-NW and BH-S on different date. The colored zones (Max ALT) indicate the maximum extent of the active layer at each borehole.

To estimate temperature, we used the data came from the AdM sample. The other sample came from very close site, was used for comparison just.

We mentioned that the model could not predict temperature at active layer because in active layer many parameters could affect resistivity as mentioned in the text, therefore, we could not estimate temperature in the active layer. We have changed the x-axis in Figure 14, and we added a ±1 shadow zone around measured temperature to show the accuracy in temperature estimation.

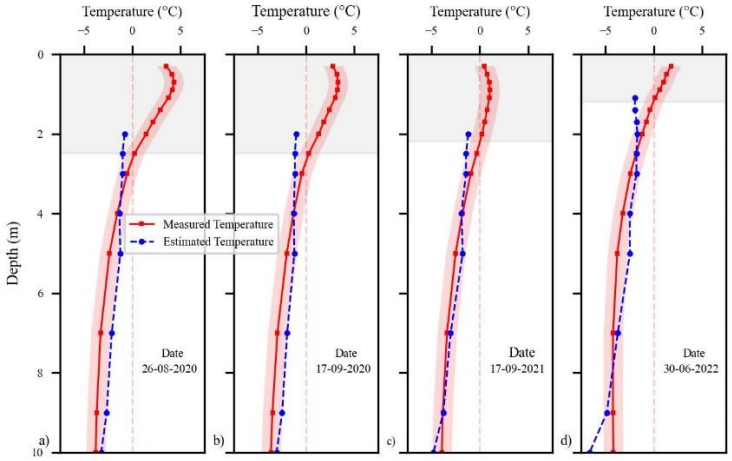


Figure 7: Comparison between measured temperatures in BH-NW and estimated temperatures derived from geophysical measurements (i.e., extracted resistivity values at different dates) using the petrophysical model in Equation 2. The gray-shaded area indicates the extent of the active layer at the time of measurement. The red-shaded zones show the ±1 °C range around the measured temperature.

14- **Hydrological dynamics:** To confidently interpret water pressures, appropriate measurements must be presented, as in Offer et al. (2025) or Scandroglio et al. (2025). Water pressure is influenced not only by the water table elevation but can also result from frozen clefts or permafrost-related constraints. Given that hydrological dynamics are listed among the study's main objectives, their treatment in the manuscript is limited. Either revise the stated objectives or expand the analysis and discussion of these processes.

**Answer**: The goal here is to test the potential of the method as a standalone low-cost approach to characterize the timing and pathways of water flows. Indeed, other approach such as piezometers are expensive and invasive. The ultimate goal of this test is to determine the potential of the method for prompt hazard assessments as water flows are a potential triggering factor of rock falls and rock avalanches (Fisher et al., 2010 ; Cathala et al., 2024). Thus, other instrumentation are not suited for prompt hazards assessment while previous studies have already validated that drops in resistivity over short time periods are due to water pressure (Offer et al., 2025). However, it is important to test the method in other topographical and lithological context and this is what we propose through our study. We know that there is water filtration to galleries. We tried with this dispositive, to detect the fractures used in drainage or the effect of water accumulation. Maybe we should adapte our dispositive to detect small events.

- **Conclusion:** (L630-631) We believe it is important to clarify in the manuscript that the measured resistivity signals on the north- and south-facing sides are similar, and that the main difference lies in your interpretation – namely, attributing high resistivity to surface drying in one case and to the presence of permafrost in the other.

  Additionally, can it truly be claimed that subsurface temperature can be "*accurately"* (L632) derived from ERT measurements using the applied petrophysical models? While the manuscript suggests a potential precision of 1°C, Figure 15 reveals discrepancies of up to ~5°C between laboratory-based and field-derived estimates. Even a precision of 1°C would be substantial in the context of permafrost studies, where internal temperatures often lie just a few degrees below freezing (e.g., Noetzli et al., 2024), and small changes can have major implications for stability and long-term thermal evolution. What about depths from 0-4 m (L634-635) – which are probably most relevant when assessing the progressive deepening of the active layer?

See **answer** above: it is important to know if these methods fail in the shallow layers, this confirm results from previous studies using thermal modelling approach and highlights research gaps for research perspectives: these depths, where many rockfalls occur (Legay et al., 2021) are the most difficult to understand and model.

**Answer**: The accuracy of 1° C came from the estimation made in figure 14. Is this accuracy is enough or not? We think that it is still an open question. It depends on the state of the permafrost. In the active layer, resistivity depends upon different parameters (water content, or saturation, water salinity, and temperature). The temperature effect on resistivity is of second order and could not use resistivity to get temperature in active layer.

Technical corrections:

-Fig 1a: the colors representing the mean annual temperature are not readable in the figure

**Answer**: We believe that these colors have no influence on the paper, reader could go back to original map to see in details.

-L26: permafrost “rocks”. **Done**

-L32: to get “temporal” variations **Done**

-L51: degradation of permafrost(?) **Done**

-L53: affected by (rather use another verb, as it is a repetition with the next sentence) **Done**

-L55: Offer et al. 2025 is not the appropriate study for rockfall monitoring, use Hartmeyer et al. 2020 instead

**Answer**: we maintained the same reference, here we are talking about studies related to effect of permafrost degradation on infrastructure.

-L59: Mamot et al. 2018 would be good to include here **Done**

-L85: the wording "in the last few years" is not in accordance with the used reference of the year 2010. This is now more than 15 years ago and not only a few years…

**Answer**: changed to: "In the last two decades"

- L173: title of the section à "Electrical resistivity-temperature relationship" (in the section you don't show conductivity results)

**Answer**: the section's title is (Electrical conductivity-temperature relationship). We present a model of the thermal dependency of electrical conductivity. And we precise that the electrical conductivity is the invers of electrical resistivity to let unspecialized reader follow our argument.

-L203: what is the snow melt water conductivity of the field site?

**Answer**: Snow melt water conductivity is ~9.2 µS/cm and the conductivity of collected water is about 150 µS/cm (and in lab we prepared solution of conductivity close to that of the site 160 µS/cm). We corrected this information in the text.

-Fig. 4: electrode number: **done**

-L293: three times "data" in a short sentence is a bit overwhelming: **Phrase removed**

-Table 1: no necessary information à consider to put it in the appendix **Answer**: removed to appendix.

-L314-317: please reformulate– it is unclear what you want to express: **Done**

-L356-357: please reformulate – it is unclear what you want to express: **Done**

## Reviewer 2:

## general comments

This manuscript presents the use of an A-ERT system at the alpine site AdM in France. Calibration in the laboratory, a petrophysical model and borehole data are supporting the interpretation of results.

**Originality (novelty): 4**
Despite the study presents an interesting application of A-ERT, this is not a novelty, since it has already been applied at other sites many years ago (e.g. Keusching et al, 2015). Due to the big measuring gaps and the authors' choice to show only a selection of results, the outcomes presented and the conclusions that are obtained here are not different from any other permafrost monitoring study.

**Answer**: Keushing et al., 2017 is 1 year of measurement, over a single profile and in a different lithology? Those are emerging methods, and we contribute to the exploration of its potential. The topography, lithology and climatic conditions are special at AdM, and the A-ERT still emerging methods where few sites are investigated using A-ERT. And we present the challenges and the advantages of using the A-ERT.

The concepts and methods used here are state-of-the-art methods in permafrost research (see Herring et al. 2023). There is no originality and novelty in the suggested data analysis and in the offered outcomes, especially due to an overall insufficient graphical presentation.

**Answer**: Not state of the art but emerging. We improved the graphical presentation of data and results.

**Scientific quality (rigour): 4**
The purposes of the work are clearly articulated. The methodology to achieve these purposes is insufficient. Example 1: The potential of A-ERT in high alpine environments is not properly evaluated with statistics in the results section. What you expect to be the core topic point of the paper (give the title) becomes just a secondary theme just mentioned in the methods.

**Answer**: Title is « « Rockwall permafrost dynamics » and this is what we explore by conducting analysis of ERT data over seasonal and interannual time periods. We have repeated and A-ERT data, we did not make statistical analysis of the times series, but we selected datasets that serve the objective of the study.

Example 2: The accuracy of temperature derived from resistivity is reported as a single number without graphical or numerical proof. Many theses are presented in the results and discussion section without being compellingly underpinned by the evidence. One important example is chapter 6.3 "Hydrogeological dynamics", which is only based on the interpretation of tomographies of the authors without any proof Let me know if there is anything else I can help you with. measure of water presence.

**Answer**: we added on the figure a red shadow zone of ±1°C, and we reduced the range of x-axis to help reviewer and reader to evaluate the accuracy of the temperature estimation. Measuring water presences requires invasive and expensive measurements. Her we test the potential of the A-ERT as a standalone, non-invasive and non-expensive approach that would

be promising in a hazard assessment approach. Some others studies have highlighted this potential and we want to validate it in another topographical and lithological settings. We found that the time series signal is not as clear as in other studies, which is important to consider regarding the site condition. But we know that water flow exists (reported by local staff who protect the galleries from these flows with metallic roof to redirect water in away from the touristic galleries.

See Figure 7 above.

As far as I can evaluate, measuring methods and techniques are valid and suitable. Information on the data processing and the inversion process is incomplete (e.g. what are the parameters used for measuring, filtering, and inverting the data?), therefore it is not possible to fully evaluate this aspect. Methods for analytical and graphical presentation of results are inadequate, from the choice of words, to layout of all the graphs, and do not reach scientific standards. One of the main suggested outcomes, the use of resistivities to obtain temperatures, is not working in winter.

**Answer**: in the new version of the manuscript, we added more information about the measuring, filtering and inversion parameters. For the processing see point 6 in response to reviewer 1.
Concerning measuring in winter: measurements in winter is not working well in most studies. But these measurements could be of great interest because this is when the heat waves from the summer propagate at depth. Many important rock falls and avalanches happen during winter (Chiarle et al., 2023). However, we show that this remains a technical challenge.

Presentation of results is faulty: some analyses are incomplete since they only describe one part of the results, not the entire situation. Some methods are presented in the result part, half of the discussion is occupied by results that should be moved to the appropriate section. This shows that the authors don't have a clear overview of the structure of their own article. Very few related works are mentioned to discuss the results.

**Answer**: we changed the results and discussion section and tried to better discuss our results in light of previous studies.

**Significance (impact): 4**
This manuscript is not contributing to changing our scientific understanding of a subject substantially and does not introduce new practical applications of broad relevance. This article definitely doesn't represent substantial progress beyond current scientific knowledge.

**Answer**: Our work does introduce new practical application: A-ERT over several years and not only several months, specific topographical settings with 3 long profiles (and not only one, usually short), specific lithologies. It also presents for the very first time an in-situ temperature-resistivity calibration, shows that the detection of water flows is not always as evident as presented in other papers, that the thawing of active layer is not detected in the same way on all faces.

**Presentation quality: 4**

Very low quality of results presentation. E.G. *"resistivity decreased over time… indicating degradation of the permafrost. However, this decrease in resistivity is minor because the observation period is short."* –> Two imprecise statements, of which the second actually contradicts the first. Impossible to read.

**Answer**: This sentence is clear and evokes previous temperature monitoring studies which both highlight permafrost degradation but also mention the lack of long term records (e.g. Noetzli et al., 2024).

The presentation of results requires a lot of improvement. Many sentences are not clear and concise, and the structure of the text needs profound improvements. The English language is just ok. The terminology is often very general and vague, presenting facts only on a qualitative level and missing quantifying differences and changes. The number of figures is acceptable, but the content and the layout of the figures are unsatisfactory.

Answer: We improved the content and the layout of the figures

**Conclusion:**
To be honest and straightforward, this text has the level of an average master's thesis - not even the best one. Given the list of experienced authors of this paper, it is actually a bit disrespectful to see work with this scarce quality that is proposed to this journal. An internal review process and much work could have made this draft acceptable, but in this condition, in my opinion, this work should be rejected. Profound improvements in all chapters are required; much more data and detailed analysis are expected to properly evidence rockwall permafrost dynamics by A-ERT. I am sure the ERTs collected at the AdM are incredibly precious and worth publishing. Therefore, I suggest that the authors strongly review the paper internally and resubmit the manuscript.

Answer: We improved the content and the layout of the figures

specific comments
*Note of the reviewer: The line number (L) refers to the sentence starting in that line, unless otherwise*
*specified.*

ABSTRACT
Missing quantitative information on PF dynamics:
**Answer**: we added information in text.

L38: "slight decrease" … quantify:
**Answer**: we added information in text.

L39: Open system / closed system – clarify or remove:
**Answer**: removed.

L46: IP measurements are not at all part of this work. Why is it in the abstract? Remove.
**Answer**: We suggest the IP which could carried out with ERT and could provide valuable information about the surface.
Changes made to clarify the sentence (This research underscores the efficacy of ERT as a promising, non-invasive tool for monitoring permafrost dynamics in Alpine environments, and

highlights the need for further methodological refinement to better resolve subsurface properties, potentially using 46 induced polarization data).

INTRODUCTION
Your introduction is missing a story and a flow. It sounds more like many pieces glued together. Some quotations are not precise. Please improve the general flow and be precise.
**Answer**: we improved the introduction.

L51: accelerates? This is not stated in the source you cite. This sentence supposes that without climate change PF degradation would be less….

L69-84: why are you citing all these methods?
**Answer**: a general review of the geophysical methods used in the permafrost context.

L85: "LAST FEW years"? last 2 decades!
**Answer**: changed to "in the last two decades".

L95: REFERENCE Please cite the first article using this methodology, not the last: someone did that more than a decade before. Substitute this reference with more appropriate works.
**Answer**: we agree with reviewer, we added older reference.

L107: "directly related" CITE SOURCE. There are many other possible interpretations of TL differences, in addition to thermal or hydrological changes… mention and cite.
**Answer**: we added references.

L110: What are the challenges? Are there other articles with these challenges or are you the first facing these problems?
**Answer**: in this study we have many challenges from the climatic conditions to the topography of the site and duration of the measurements, they are almost unique. It is not a simple ERT measurements of a short profile without topographical variation.

L111: "However, it could provide valuable information about the evolution of permafrost." Unnecessary sentence, remove. Even before reading your article, I can tell you will get valuable information.
**Answer:** No change was made.

L124: You use only one borehole in this article. That the others are there is only partially important. STUDY SITE This introduction to the study site is poor. You include secondary information but forget important points: what previous permafrost/cryo-research (only Magnin 2025 and 2015?). No other studies here? What about rock stability? Are there known/visible/investigated effects? Add some information on the region's climatology (precipitation amount and type, snow cover, etc..)

**Answer**: I used data from one of the boreholes and now we added in the appendix A information about the second borehole (BH-S), where we have enough ERT data to analyses. We have air temperature information but not precipitation, which is very important information to consider for the future studies.

L 127: remove "iconic":

**Answer**: Ok, it was removed.

L129-135: Rephrase, shorten, keep only the important information, and remove what is superficial (e.g. “Panoramic Mont-Blanc”):
**Answer**: we did the necessary changes.

Fig. 1– A: You use areal images with some MARST superimposed. These are impossible to read, both the aerial images and the temperatures. Please replace with proper maps at the right scale to see the right location. D: I think it would be better to have snow cover images from all sides to evaluate snow accumulation. Replace the image if possible.
**Answer**: we think the figure is clear, and the caption contains the reference to the origin, for more details. Actually. we don’t have photo with the snow cover at the period of measurements.

FIG2 – Please plot a longer time series. Permafrost dynamics often present a delayed response to thermal signals (e.g., as shown in Hauck und Hilblich, 2024). 10 years minimum; the longer, the better. What is the difference between your temperature and the climatic average (30-year reference period)?
**Answer**: The idea here to get some information about the climate condition at the period of the ERT measurements. We put a reference to get more details about the temperature variation over the last 15 years (Magnin et al. 2024), we think this information is sufficient for the objective of this study.

L137: “tend to be steep” - Replace with some measures, like average steepness in degrees!
“in places” -> partially
**Answer**: we added the information about the average steepness.

L143 move reference to Fig 1 at the end of the sentence here. **Done**

L144: “were” -> was. **Done**

Fig4: y-Axis label is not English:
**Answer**: correction was done.

L150: ALT – remove the explanation after “i.e.”, it is not necessary in this context.
**Answer**: we think that as there are non-specialists who will read the paper and may not be familiar with the permafrost expressions and abbreviations. No change was made,

L153: “all along the year” – remove. Otherwise, it would not be permafrost. “see details in” – remove. **Done**

L163-166: Avoid boring repetitions in text. Rephrase: **Done**

**METHODS**
Are some of these methods take form from other previous studies? If so, please cite them.
**Answer**: we added references.

L201: What is the size of the sample?
**Answer**: it is a cubic of 5*5*5 $cm^3$. We added this information in the text.

L211: Ok the frequency, what about the other setting used for measuring in the lab? Current injected? Electrode resistance? Stacks? Error limit? Reciprocal measurements? The same for field measurements. Please add all the ABEM setting used for measurements, I suggest in tabular form.
**Answer**: we added references for lab measurements. And we added information about field acquisition parameters.

L219: Move the measure of porosity at the beginning of the chapter, where you present the sample. **Done**

L236: "The installation of cable was gradual from June 2020 to March 2021."
**Answer**: the accumulation of snow at the east face was the raison for that.

L241: "specially designed jumper" - Designed for this study or before? It would be good to provide an image of the field set-up: electrodes, jumper, anchors.
**Answer**: we don't think that will add valuable information, see photo below.

Photo 1: specially designed stainless-steel jumper used to attach the cable takeout onto the climbing bolt, with maximum electrical contact (duplicated electrode).

L241: "The electrodes remained embedded in the rock wall for all subsequent resistivity measurements." That's pretty obvious if you use climbing bolts. Remove.
**Answer**: we agree with reviewer, information removed.

L250: "Configuration" -> array. Your explanation of the Wenner array is approximate and insufficient. I think there is no need to explain it in this context. Therefore, I suggest removing the content of the brackets.
**Answer**: information removed.

L261: What about the third profile? Add the information at least to supplementary material, even if incomplete. When exactly was it damaged by lightning? No useful data?
**Answer**: it was damaged by lightning, few days after installation, this is characterized by a steady value of the contact resistances (no variation over time).

Photo 2: Effect of lightning on the ERT cables

L268: One comma too much or the point. **Done**

L269: Either you list the several reasons or you rephrase the sentence. **Done**

L270: How many datasets?
**Answer**: We added and information about this point.

Figure 4: Please add more information on the reason for gaps: what happened in October 2021, summer 22, winter 2022-23, and spring 2023? Improve caption (are data missing ONLY due to cable defects?). I suggest adding a table/list of the issues that you experienced. This is a very interesting "learning lesson" for the bedrock permafrost community.
Answer: information added to text.

Please also comment in detail on software issues …you just mention it shortly. I would also suggest adding some statistics on the efficiency of the A-ERT in the results and talk about possible improvements in the discussion part. Please mention if you used reciprocal measurements and if not, why.

**Answer**: the issues are related to mesh generation when the site has a sharp topography like Res2Dinv. No reciprocal measurements were conducted, we made 3 stacks to evaluate the error at each measurement.

**DATA PROCESSING**
L284: "We tolerated…pseudo-section." – Repetitions, rephrase in a clearer way.
**Done**

L288: How did you detect the outliers? Please be precise.
**Answer**: We analyzed few data sets from different times (see point 6 in response to reviewer 1).

L289: The fact that most datasets have more than 80% of the data is because of your previous selection (up to 4 unconnected electrodes). Rephrase for clarity. Do you also happen to have 100% data? Interesting that this is never the case in the data you selected. Or you don't reach that because of the outliers? In that case, I'm very curious about the outlier selection.
Answer: yes, there are completed datasets (max 154 of 155 datum points), especially in august and September.

L291: Table 1 is a bit of a waste of space since it represents only a few measurements. I would move it to supporting material. The space could contain much more information… Use this space (almost a whole page) to present statistics about all the measurements you did. Your novelty is the A-ERT, here you have the chance to show numbers about all the data measured and you should use it. What is the overall reliability of this system? Is this changing from summer to winter? Further statistics should be addressed and presented with graphs or tables.
**Answer**: We added in the text information

L299: "The topography is characterized…" This sentence goes in the study site section, not here. The problem is not the steep topography since you measure perpendicular, but the changes

of direction when you unite more transects! Actually, the software you use for the inversion can deal very well with steep topography.
**Answer**: we agree with reviewer about software and we moved the sentence into the study site section.

L303: package -> library
: Please also present the parameters of the inversion in a table.
**Answer**: we added information about inversion.

L306: A linear error model is always defined by two parameters. Do you neglect the absolute error? The relative error seems to be in a realistic range, but on which base did you choose it? References? Have you conducted a sensitivity analysis on the data to check the influence of the selected error model?
**Answer**: the absolute error has no or very small (no detectable) influence on the inverted result. We tested different relative error, higher value of relative error we get faster convergence and higher larger dispersion of data.

L310: You are interpreting the data. Therefore, I would rename the chapter "results and interpretation." **Done**

L 311 raw data – before filter?
**Answer**: yes, before filtering. And we built our filter after analyzing these data sets. Completed data sets and com from different dates.

L314: How did you compute the apparent resistivities? Please add at least one sentence on how this information is obtained.
**Answer**: we used pyGimli library to calculate the apparent resistivity using the measured resistance (after taking into account the real positions of electrodes). And it is known for PyGimli users the use of resistance instead of apparent resistivity as input for the inversion.

L315: (i.e. …) remove text in brackets, is a repetition. **Done**

Fig 5: I find it very hard to read this figure. I think the graph style (thin bars) and the overall layout do not clearly express your message. You should guide and facilitate your reader in the interpretation of the data in the figure. Consider reviewing the layout. I would use lines instead of bars and superimpose a grid on all graphs. Add labels for summer/ winter to facilitate understanding. Consider differentiating between years by using improved color schemes … there is a lot that can be done. I would also consider a logarithmic y-axis, which is typical in resistivity graphs.
**Answer**: We simplified it and removed part of data and we kept data that could support the objective of the figure.
**Answer:**
L320: the "*high values near the surface"* are only for 3 out of 5 datasets. Why? What is happening to "*the fractured area filled with air"* in 2020, August and September?
**Answer:**
L324: What is your interpretation of the different values for the NW profile in May 2022? And for the S profile in April 2021?
**Answer**: why this comparison between data of different date, different profiles! simply, the snowmelt or ice melt in May 2022 could be the raison of decreases of apparent resistivities at NW side.

L327: “various” -> substitute with “selected”. How did you select these quadrupoles out of the 155 of your profile? Why these quadrupoles and not others? Fig6: Add grid. Why are you plotting only a selection of your data? I don’t see the reason in this Figure. I understand you cannot show a tomogram for each day of measurement, but this simple graph can host all measured values. I expect the authors to improve the Figure, adding all available measurements for the 8 selected quadrupoles. Otherwise, the advantages of the A-ERT are lost, and your study is comparable to that of permafrost campaigns with single repetitions. Consider also reporting the theoretical depth-of-investigation (DOI) for each quadrupole. This is more interesting than the electrode numbers.

**Answer**: Figure was removed. And replaced by a presentation of raw datasets with time series of few quadrupoles.

L331: *“Furthermore, the seasonal variation of apparent resistivity is more pronounced for shallow data.”* True for the NW profile, but it seems that in the S profile, this is not the case. In fact, green line (DOI = 3) and the red line (DOI = 10) behave parallel – apart from April/Mai
**Answer**: there is less variation at the green line at S side, may be because of the topography effect, with the large distance between A and B.

2022. Fig7. Which additional knowledge is the insert adding to the whole picture? Actually, you are plotting twice the same information. I don’t see the point in doing it and would remove it. Further on, why are P1 and P4 perpendicular to the surface while P2 and P3 are not? Did you filter this image for outliers? What is the low resistivity point in the middle of the S profile?
**Answer**: insert figure was removed. We explained our idea with the profiles from the time laps inversion (Fig 9 in new version).

L351-355: I can accept the names “warm-colored”, “cold-colors”, “moderate resistivity”, etc… but the whole concept behind this sentence it too general and undefined. Please be precise by numerically defining (if needed, also with a range of errors) your resistivity limits for frozen and unfrozen part, as well as the active layer. This should be also clearly visible in the color bar of your images.
**Answer**: information was added in the text.

L356: do S and NW walls have the same aspect? What do you mean here by aspect? Please explain why the resistivity values are “expected” to be the same on two opposite faces of the mountain –this is new to me.
**Answer**: We mentioned in the text that the profile S starts at the south face and finish down in the north face (Line 235 version 1) and in figure 1.c we put both profiles. that is why we expect the same values of resistivities.

L369: *“This variation is attributed to heat transfer, particularly in areas close to the sun-exposed face.”* please explain better this concept, why?
**Answer**: We explained in the text

Fig8: add antropogenic installation and electrode numbers.
**Done**

L382: How can you differentiate at this stage whether the high resistivities are due to dry layers or to permafrost?? Or maybe just to less fractured bedrock?

**Answer**: Our knowledge of the site

L 386 *"On the other hand…"* move this whole sentence to methods. Here it´s not the right place. Also the sentence at L394 "T*he last 10 electrodes…*" should be moved to methods.
**Answer**: we moved the sentences.

Fig 9: Hard to read the date. Improve. Why don't you show 25-09-2021?
**Answer**: Figure was changed.

Fig 10: sometimes 1 month in between, sometimes 7 months. You are comparing different entities in the same graph.
**Answer**: Figure was changed.

L404: Mot true, I see relevant differences also in the PF area. How did you quantify "the most significant variations "??
**Answer**: the relevant difference close to surface is higher than 10 or less than 0.1 of resistivity variation ratio. Other anomalies deeper could be related to the heat wave or cool wave.

L407: *"A more prominent cool-colored zone (more permafrost)."* This sentence and all the other similar ones in this text would have been acceptable 2 decades ago, at the beginning of ERT research. Nowadays, it is required to quantify changes and be more precise.
**Answer**: we added more information in the text.
L410: This is a thesis. demonstrate it. Limit yourself to your results, no citations in the result part.
**Answer**: we changed this part.

L424: This sentence is obvious. Remove. **Done**

Fig. 11: The plot order of tomograms is not helping the reader to understand PF dynamics.
**Answer**: The figure was simplified

L454: This sentence is not true.
**Answer**: Changed.

L465: when do you have snowmelt in this area? provide data or cite literature
**Answer**: we don't have the data about this, we could notice the air temperature.

L 458: All teories, but you need to prove it.
**Answer**: we tried to prove this information in the new text.

L469: Is water infiltration the only explanation you have for these processes?
**Answer**: yes the only for the moment

L509: ok, you are using inverted resistivities, but I find it very hazardous to analyze these values at this detail (0.5m resolution). These are interpolated values from an inversion model ... there are many uncertainties you are not considering. Your measuring resolution is much higher.
**Answer**: we agree with reviewer that close to surface is interpolated information and we mentioned that in text. We tried to avoid discussing the resistivities close to surface.

L540: Which are “the other parameters” you are mentioning? Which parameters are you using in the petrophysical model? Are they constant along the transect?
**Answer**: all used parameters were explained (section 3) and they are all constant over time.

L544: The only quantitative result of the whole paper cannot be validated because your graphs don't have the proper scale… improve!
**Answer**: the figure was improved.

L546: Calibration is not working for cold temperatures!
**Answer**: yes, we think it is related to the high CR.

L550: *“The estimated temperature presented in Figures 14 indicate that the proposed model (Equation 2) can accurately reproduce the temperature”*. This is not the aim of the paper, since this model (equation 2) has been proven already in other articles. Remove. I also don’t agree with the use of accurate, since you don’t show any measure of this. The graphs have a range of +/- 10 °C and it is not possible to compare precisely the results.
**Answer**: the figure was improved.

L552: How would you adjust inversion parameters? According to measured temperatures? Random coment not Doing so, you would calibrate the resistivity values with the same temperatures you use to validate.
**Answer**: We did time lapse inversion. So, the RMS could be high for some results or times. Individual inversion could be better controlled to reduce RMS. In our response to reviewer 1 you can find more information about inversion and used parameters.

L556: “However…” Here again, you contradict your previous sentence. Is the model working here or not?
**Answer**: we intended to create a 2D tomogram of the temperature distribution as done in Duvillard et al., (2021), but the conductive zone at AdM made this approach unsuitable. Therefore, we limited our analysis to estimations and comparison in 1D.

L557: What does it mean that the infrastructure creates a "conductive zone"? For temperature or for resistivity? How did you evaluate this effect? Could you measure it and prove it? or is this just an assumption you are making?
**Answer**, we could notice it is effect on the tomograms and on the extracted resistivities of the P2.
Figure 14: Not possible to evaluate the error with this visualization. How do you explain the differences in Figure d) at 10 m depth?
**Answer**: as you know that in ERT, we lose of sensitivity and precision with depth. One point out of range.
Figure 15: Also here, again, you are poorly using the visualization possibilities of a figure. There is no effort in helping the reader to understand your messages. Grid, zoom, colors, and much more can be really improved.
**Answer**: the figure was improved.
L585: “smaller dispositive” – Wrong terminology: what do you mean?
**Answer**: changed to “shorter electrode spacing configuration”.

L586: “Clarity” – Wrong terminology: choose a proper word. – Poor discussion style: Many hypotheses are without references and without a real explanation. – When are you varying pore size?

**Answer**: changed to “the observed discrepancy “.

L601: “we did observe several instances that could be classified as evidence of water flux” there is really no evidence for it. This is one possible explanation but you need to prove that. Because the other researchers are working on this topic, it doesn’t mean that you can also just make out water in your ERTs without justifying it. For example, show us measurements of rain events or snow-melt rates in the periods of interest.
**Answer**: we don’t have precipitation data of the site over the measurements period to make this analyze. Maybe in the future work we will take into account this important information.

L607: “Near-surface desaturation” – this could be measured in the field to prove your theory.
**Answer**: it is difficult to realize correctly in rock fractured zone, and the data was carried out few years ago without estimation of saturation.

L618: To be honest, you cannot say much about climatic variations with 3 years of data…
**Answer**: there is a clear decrease at both sides. Despite it is small, we mentioned that in the text. That does not mean we could not interpret dataset of three years, or that we should wait to get ten years dataset.

L620: “*That the temperature-dependency of resistivity in field conditions is less pronounced than in*
*controlled laboratory settings*.”
I think this is a dangerous statement, which is not properly based on evidence from your study. The provided data are too little and the analysis conducted not sufficient. Probably you are just comparing two different things: one single sample in the lab and many different samples in the field, with conditions that change in space – heterogeneity, as you say. Of course, in the field you have more variables, but this doesn’t mean that “the temperature-resistivity dependency is less pronounced”. With some effort you could probably reproduce all field conditions in the lab….
**Answer**: we changed the term. However, it was used to describe the observation from the field data and the context of site explained in the text (i.e., discontinuity at large scale fractures or faults that could be filled with ice, air or water), noticed this, however, we explained in the text the raison behind such results as the reviewer mentioned the heterogeneity.
The second point about reproduce the filed condition in lab: we disagree with this point, it is very difficult to get or to predict the discontinuity at large scale in lab.

L628: “*we were able to characterize the active layer and identify significant seasonal and multiannual changes in permafrost dynamics. Importantly, we observed that the ALT varied significantly from one face to another*” - What is your innovation? This knowledge is state-of-the-art since almost 20 years in permafrost research.
No comment

L631: “climate signal” - the choice of this word is unjustified and misleading in this short-term study. No data presented here has the appropriate scale for climate analysis.
**Answer**: we changed the term and added the period of the observation (2 years or 4 years).

L636: Your “*assessment of the hydrogeological system*” is absent and your hypothesis on these fluxes lacks complete proofs that demonstrate the presence of water.
**Answer**: there are some information that could not be confirmed with the data and dispositive used so, we propose to use shorter electrode spacing in the next study.